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Science/Art - Art/Science: Case Studies of the Development of a Professional Art Product

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Science/art - art/science: Case studies of the development of a professional art product

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Abstract

The objective of this study was to follow the cognitive and creative processes demonstrated by student research participants as they integrated a developing knowledge of “big” science, as practiced at the Department of Energy’s Lawrence Livermore National Laboratory, into a personal and idiosyncratic visual, graphical, or multimedia product. The participants, all non-scientists, involved in this process, attended a series of design classes, sponsored by the Laboratory at the Art Center College of Design in Pasadena, California. As a result of this study, we have become particularly interested in the possibility of similar characteristics between scientists and artists. We have also become interested in the different processes that can be used to teach science to non-scientists, so that they are able to understand and portray scientific information.

Introduction

In recent years organizations such as the American Association for the Advancement of Science (AAAS) (1990, 1993), the National Center on Education and the Economy (NCEE) (1995), the National Research Council (NRC) (1994), and the National Science Foundation (NSF) (1990, 1991) have spearheaded major efforts in the United States to promote a broader scientific literacy among the non-scientific general populace.

In 1995, the Lawrence Livermore National Laboratory (LLNL) contracted the Art Center College of Design (ACCD) in Pasadena, California, to develop, in a series of design classes, a new “corporate image” for the Laboratory.

The Lawrence Livermore National Laboratory (LLNL) is a multidisciplinary research and development center operated by the University of California for the U. S. Department of Energy. Its mission is to serve as a national resource in applied science and engineering to meet national needs.

The Art Center College of Design (ACCD) is a center for designers and visual arts professionals. Its mission is to offer an education in design and the visual arts, grounded in fundamentals. Its programs challenge students to “exceed their preconceived limits, and enable them to enter the professional world with confidence in their skills, abilities, and potential.”

The original ACCD class, entitled “Creating an Identity for a National Laboratory,” placed emphasis on the design of an emblem (Figure 1) , stationery letterhead (Figure 2) , name cards (Figure 3) , identification badges (Figure 4) , and other traditional corporate artifacts (Figure 5).

Figure 1. Emblem.

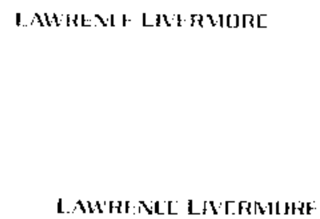

Figure 2. Stationery.

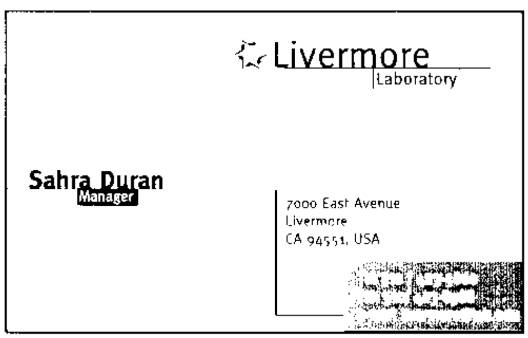

Figure 3. Name Card.

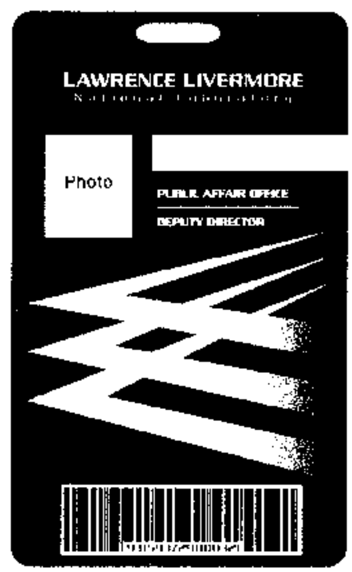

Figure 4. Identification Badge.

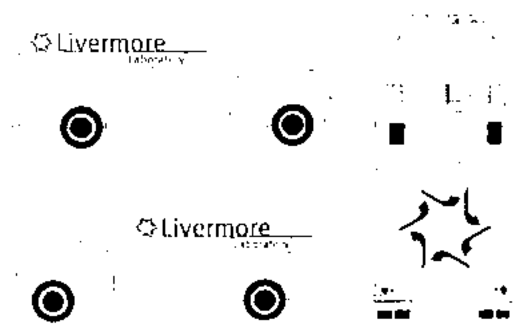

Figure 5. Corporate Artifacts.

By the spring of 1996, not only had the title of the class changed to "Creating a Visual Synergy for Science," but so had the emphasis. The art students were asked to use the knowledge they had gained of the Laboratory's scientific programs as the basis for a product that was not corporate in nature. Rather, the students were asked to create a visual, graphical, or multimedia product that depicted their personal, idiosyncratic understanding of the nature of science at the Laboratory. The project had become a lesson in the development of scientific literacy about "big ideas" and its expression in an artistic product.

The objective of this study was to follow the cognitive and creative processes demonstrated by the student research participants as they were integrating their developing knowledge of the Laboratory's science into this product.

The research team investigated this "science into art" process from two different perspectives. Sesko has worked at the Laboratory for 17 years in various educational capacities that have involved teaching about the Laboratory's science to the general public, to students, and to teachers. He also has taught computer programming to gifted children at LLNL. Marchant brought to the research the perspective of the artist. She teaches both Art History and Studio for Cosumnes River College and Sacramento City College. Further, both have done work in the area of creativity, utilizing drawing and computer programming as learning strategies. We believe these two different lenses enabled the team to investigate how the creative process developed an artistic product from scientific information, and to offer new insights into how science can be taught in different ways to different audiences.

Background

The scientific literacy efforts of the AAAS (1990, 1993), NCEE (1995), the NRC (1994), and the NSF (1990, 1991) have sparked much discussion in the United States on the importance of a broader scientific literacy among the non-scientific general populace.

However, despite this discussion, our background research has found very little in the literature to explain how the general populace comes to an understanding of what science is, and why it is pervasive in our lives.

In the original traditional ACCD course, "Creating an Identity for a National Laboratory," students kept artists' sketch books of their ideas. The approach was four weeks of research into the client, and ten weeks of product development. At the end of the course, each student would have created a "book" that is his or her visual, graphical, and often textual, conception of how the new corporate image would appear, including an emblem, stationary letterhead, name cards, identification badges, and other traditional corporate artifacts.

Under a new concept developed by the professors of graphic arts, and incorporated into the course entitled "Creating a Visual Synergy for Science," the students were asked to do ten weeks of research and four weeks of product development. As artists, these students had <u>chosen</u> to have a limited academic background in science -- not much beyond what was required of them in school. During the 14 week course, the students did extensive research on the kind of "big" science that is conducted at LLNL. They came to our Laboratory and toured various departments. They met with and spoke with LLNL scientists. They were also asked to be more reflective of the processes they used to develop the product.

The reasoning for this new approach to the design process is best explained by the two professors who developed the idea (italics ours):

> "There has never been a more challenging and demanding time for graphic design. Today students must not only be proficient in the traditional areas of typography, layout, materials, and color, but new technology, as well. They must embrace interactive media with *critical thinking and exploration*.
>
> "We educate designers of the future, designers who will shape industry, not be consumed by it. We seek those who *will look beyond the surface and make a complex idea clear*. They exemplify cultural diversity without assimilation and simplify without sacrificing aesthetics. Our designers must create individual statements, yet function in a team environment. *They will need an understanding of cognitive science, science, history, politics, and theater* to prevail. Effective design comes from knowledgeable designers.
>
> "Our designers will not compete -- they will set the standard" (Miho & Thomas, 1996).

We believe this study offers a unique perspective on science education, art education, cognitive change, and creativity. We also believe that this study offers a different perspective on public understanding of science.

Literature

We found no specific studies in the science education literature that addressed the understanding of science through a medium other than traditional school-based science courses. The literature in the field of art as such a transfer medium is similarly weak. For this reason, we turned to the bodies of work on art education, creativity, scientific literacy, and the characteristics of artists and scientists. This literature provided us with broad conceptual themes, rather than qualitative or quantitative research.

Modern science, whether in the classroom or in the laboratory, is arguably based on two key assumptions: 1) that there is an underlying order to the seeming disorder in our world; 2) that events in nature have causes which can be identified and understood. The new approaches to science encourage learners (children and adults) to view and understand science as an open-ended exploration of the experiences that happen in the world around us, rather than as a closed body of knowledge to be memorized and repeated by rote. These new approaches advocate a view of science as a set of continually-revised theories of what might be, rather than absolute explanations of what is (AAAS, 1990, 1993; NCEE, 1995; NRC, 1994; NSF, 1990, 1991). In the realm of creativity, these current ideas of science education are supported by Koestler (1964), but are, surprisingly, not referred to in the science literacy literature.

These assumptions imply that science is a collective -- a social -- practice, with individuals across cultures and time sharing observations, hunches, insights, as well as successes and failures. A particular example of this concept can be found in Newman, Griffin, and Cole (1984). The understanding of our world is such an immense undertaking that it would be mistaken to assume that science could be practiced any other way. Similar thinking from the field of creativity can be found in Hardison (1989) and Stoppard (1994).

Recent thinking about science believes that science then becomes an effort in which anyone can engage, even a small child who may observe simple harmonic motion in a slinky. This kind of behavior is described in Papert (1984) and also in Kozol (1980).

The new vision of science means that we all ask a lot of questions and make many observations, that we debate, but that we remain open to all possibilities, that we remain skeptical to minimize the risk of being misled or fooled. Perhaps it simply means that all adults and children rediscover or retain the wonder of our youth. Again, the importance of this child-like attitude is argued in Papert (1984). These arguments are also made in Hardison (1989), Koestler (1964), and Kozol (1980).

In content, the AAAS (1990, 1993), proposes emphasis on the “big ideas” of science, rather than the memorization of facts; systematic questioning and investigation, rather than acceptance of reading or lecture material. Such activities stress skills such as experimentation, rather than instructions from a book. Such activities encourage concentration on the major themes, and examination of these themes in greater depth, rather than concentrating on lower level thinking skills. Loewen (1995) makes these same arguments against textbooks, facts, and lectures.

In process, the new ideas stress hands-on, minds-on approaches to science, including investigation, discovery, and the application of science and technology in appropriate ways. In other words, learners are not just "learning science"; they actually are doing science (AAAS, 1990, 1993; NCEE, 1995; NRC, 1994; NSF, 1990, 1991).

The concepts expressed in these new visions of science literacy and science teaching and learning are the basis of the research environment in which the Art Center students worked. It was this environment and the products of this environment that we studied.

During the course of the field work, we became interested in the possibility of similar characteristics between scientists and artists. Literary sources in these areas are Roe (1952) for scientists and Gardner (1982, 1993) for artists. Roe investigated the characteristics of 64 eminent scientists. Gardner explored creativity in art in general in the 1982 work, and specific artists in the 1993 work.

Methodology

Process

The investigatory process began when students enrolled in the class. Their instructor informed them on the first day that we would like to do a research project based on the work they would be doing during the course of the class. At the second class meeting, we described the nature of our work and recruited participants. We gave those who had decided to participate a written description of the project and informed consent forms. At this time we also asked the students to maintain both journals and artist sketch books of their work, which we would collect and use for analysis.

Those who agreed to participate were first asked to answer a short questionnaire about their experiences with, and attitudes about, science before this class. These answers became data for comparison with the thematic literature.

As the class progressed, the students had access to numerous articles, brochures, reports, and other materials published by and for the Laboratory. They also did their own research about the Laboratory through newspapers, news magazines, the World Wide Web, and other sources of their own choosing.

The fourth class session was devoted to an all-day tour of the Laboratory facilities conducted by scientists in various areas, lunch, and a an hour-long meeting with one of the Laboratory's scientists. We encouraged the students to ask questions and participate in a dialogue with all whom they met.

On the last day of the class, we observed the students' presentations of their final products, listened to the instructor's comments on the work, and then conducted interviews with those who had chosen to participate.

Later in the data gathering process, we asked the participants to complete a second questionnaire.

Data collection

An understanding of the personal interactions these students had with art and science could not be addressed by either the theoretical literature or the questionnaires alone. The personal and idiosyncratic nature of these issues indicated that this information could best be gathered from an interview process.

We did not interview the students in any particular order or sequence. This was due to the fact that they were interviewed at their convenience, not ours. We interviewed them individually for 60 minutes, using techniques found to be effective by Fine and Sandstrom (1988), McCracken (1988), Seidman (1991), and Yin (1989. The data were highly reflective and personal.

The interview questions were open-ended, with patterns of thinking, and many other concepts to emerge from the answers to the questions. The question development techniques were derived from, but were not exclusive to, ethnographic interviewing, as discussed by Spindler (1988) and Wilcox (1988). These techniques included the use of open-ended questions, the judicious use of probes, and the use of extensive follow-up questions.

We also used questionnaires and materials produced by the subjects in the process of creating a depiction for LLNL. These materials included both written and artistically rendered notes used by the students in the development of their depiction, including their ideas about science and about the Laboratory. We also analyzed the final product of the students' endeavors, their "book." Our research methodology was to analyze these journals and sketch books to determine themes that are alike, similar, and divergent from one and other.

Following the interviews we used the narrative data in conjunction with the textual material to determine if there was a grounded theory that could be developed to begin to explain the process of how non-scientists, particularly artists, come to an understanding of science.

Data analysis

The theoretical framework was also exploratory. The research participants elucidated the issues in the study from their own observations, using their own words, drawings, and "marks." We conducted the research from a phenomenological perspective: what the structure and essence of the science art experience phenomenon was for these participants.

We first transcribed the interview data using a word processor, then organized them into a table. After the transcription was complete, we did the coding directly. Using the search capability of the word processor, we found the key codes and themes that we had determined from the participants throughout the text. We then entered these into a cell of the table next to the interview segment in which they appeared. This procedure allowed the codes and themes to stand out separately from the text and made understanding of the accompanying text easier.

The data were compared and contrasted to see what particular codes and themes emerged. The development of codes and themes resulted from particular suggestions also found in McCracken (1988) and Seidman (1991).

In this study, each participant became, in effect, a separate case study. In this sense, each participant vignette is a literal replication of the experiment. When compared and contrasted, the cross-participant codes and themes become a multi-case study that also yields the possibility of replication. This type of design is defined and described by Yin (1989).

We coded the data for analysis according to the concepts developed by Strauss and Corbin (1991), including open, axial, and selective coding. Codes were used to determine themes, which were considered provisional until quite late in the process. The importance of the theme was relative, as well. While some areas seemed of great importance to one of us, these same themes may have been unimportant to the other.

Unlike studies done in laboratory situations with specific measures to analyze the results of specific variables, this study investigated the participants in informal situations, with no specific variables. There were no preconceptions of what results would be found. Newman, Griffin, & Cole (1984) argue that, in informal situations where the data are emergent, it is not possible to control for specific variables; nor is it possible to predict the kinds of data that might be obtained. Without specific variables, it is not possible to develop formal measures of data that can apply to the material obtained. The data for this study were the ideas, opinions, and revelations of the participants. They are measured by comparison and contrast, not by specific tests.

Data presentation

The work produced a rich, descriptive narrative that identified modes of thought and interactions the artists had with science. Stories, narratives, and anecdotes have always been a way of creating meaning; they are one way of knowing. The research participants explained their experiences with art and science in the stories they told during their interviews. The students selected details of their experiences, reflected upon them, made personal sense of them, then narrated them to us. Taken together, the stories coalesced into our understanding of the student's experiences. We attempted to discover what was both consistent and different among these stories. This analysis became our understanding of how these participants think about and express science through their art. I. E. Seidman (1991) calls this process "the ability of people to symbolize their experience through language."

The individual student data were written up as vignettes of each student's experience in the student's own words. The elements that emerge from the work with the questionnaires, the interviews, the artist sketch books, the journals, and the final project materials comprise the presentation of the data.

Participants

The sample selected for this study is what Patton (1990) would call "typical case" sampling (p. 173). This kind of sample can be taken from survey or similar data. Its purpose is to provide a "qualitative profile of one or more typical cases to describe what is typical...not to make generalized statements.... The sample is illustrative, not definitive." (p. 173)
The five participants in this study were self-selected from four classes which took place over a period of nearly two years.

The five volunteer participants were all Caucasian males in their early twenties: one was 23; one was 25; three were 24. The youngest was a senior student, the other four were juniors. Four were majoring in Graphics/Packaging, one majored in Communication design.

Data

One of our initial investigations involved the characteristics that these students had in relationship to documented characteristics of scientists. We turned to Roe (1952) for these characteristics, as this was a seminal work. While our data are slim, they show promise for future study.

Roe's data, and our participants' responses from our questionnaires have been organized into the following table:

<u>Participant characteristics</u>

Table 1. Characteristics of Participants Against Roe's Characteristics of Scientists - Family Background

	1	2	3	4	5
First-born child	T	T	T	T	T
Middle-class family	T	T	T	T	T
Son of a professional	T	T	T	T	T
Sickly child	F	T	F	F	F
Lost a parent early	F	F	F	T	F
Rebelliousness	F	F	T	F	F
Learning Important in family	T	T	T	T	T
Independent of parental relations	T	F	F	T	F

T = true; F = false; NA = not applicable; ND = no data

It was the remarkable similarity in family life between the artist-students and the scientists that influenced us to pursue this comparison further. There was enough information from only five participants to give us a clue in this direction. These data are in Table 1. The main differences between the students and the scientists were 1) that the students were uniformly healthy as children, 2) the relative lack of independence from parental relations. Sickliness or loss of a parent may have been more prevalent in 1952 than now. According to Roe, “The biologists and physical scientists manifested a quite remarkable independence of parental relations and were without guilt feelings about it, while the social scientists showed many dependent attitudes, much rebelliousness. . . .”(pp. 105-106). Our participants were not independent, but neither were they rebellious. There is a general, across the board, emphasis on the importance of learning in their families, as there was for Roe’s scientists.

Table 2. Characteristics of Participants Against Roe’s Characteristics of Scientists - Social Life

	1	2	3	4	5
Feel lonely and “different	F	F	F	F	F
Shy and aloof from classmates	T	T	T	F	F
Married late	N A	N A	N A	N A	N A
Has few recreations	T	T	F	T	T
Movies bore him	F	F	F	T	F
Moderate interest in girls	T	T	F	T	F
Avoids social affairs	F	F	F	F	F

T = true; F = false; NA = not applicable; ND = no data

In the area of social life (Table 2), again our data are sparse, but they show a strong similarity to the social lives Roe describes for social scientists: “Whereas the characteristic pattern among the biologists and physicists is that of the shy, lonely, over-intellectualized boy, among the social scientists the characteristic picture is very different. They got into social activity and intensive and extensive dating at an early age. . . . It is true only in general, of course; even among the theoretical physicists there are some ardent party-goers” (p. 110). Our data indicate that the students did not feel lonely or “different” as children. They were, however, shy with people with whom they were not well acquainted. Our data also show that they enjoy social activities, including the cinema. Like the physicists in Roe’s study these students had and continue to have few recreational activities, usually devoting themselves to one or two activities such as surfing, snowboarding, reading, etc. One point is that these students have a more than moderate interest in the opposite sex.

Table 3. Characteristics of Participants Against Roe's Characteristics of Scientists-Intellectual Life

	1	2	3	4	5
High IQ	Y	ND	ND	ND	ND
Non-religious	T	F	T	T	T
Not political	T	T	T	F	T
Great deal of reading	F	T	T	F	F
Good on verbal tests	F	T	T	F	T
Good on spatial tests	ND	T	ND	T	T
Good at math tests	T	T	F	T	T
Visual imagery	T	T	T	T	T

T = true; F = false; NA = not applicable; ND = no data

As with Roe's scientists, our artist-students are, for the most part, not religious, and are also apolitical. We were also interested in the similarities found in the use of visual imagery. Roe (p.106) found that, "The biologists and the experimental physicists tend strongly to dependence upon visual imagery in their thinking--images of concrete objects and elaborate diagrams or the like." The theoretical physicists and social scientists tend to verbalization in their thinking--a kind of talking to themselves. All groups report a considerable amount of imageless thinking, particularly at crucial points. In terms of testing, our students are mixed; similarly are Roe's scientists: "Among the biologists, the geneticists and biochemists do relatively better on the nonverbal tests than on the verbal, and the other biologists tend to do relatively better on the verbal. Among the physicists there is some tendency for theorists to do relatively better on the verbal and for the experimentalists to do relatively better on the spatial test. Among the social scientists the experimental psychologists do relatively better on the spatial or mathematical than on the verbal test, and the reverse is true of the other psychologists and anthropologists" (p. 105).

Table 4. Characteristics of Participants Against Roe's Characteristics of Scientists-Professional Life

	1	2	3	4	5
Decided vocation as a college junior or senior	F	F	F	F	F
Satisfied with chosen vocation	ND	ND	T	T	ND
Works hard and devotedly	T	T	T	T	T

T = true; F = false; NA = not applicable; ND = no data

Professional life (Table 4) is one area where there was a great difference between Roe's scientists and our artists. Although all five are either juniors or seniors in college, only one of our participants has decided on an exact profession, while all of them know that graphic arts will be a part of whatever vocation they finally do choose. The one who has decided did not make the choice at ACCD, but in high school. For Roe's scientists, "It is of considerable interest that over half of these men did not decide upon their vocations until they were juniors or seniors in college. More important, perhaps, than when they decided, is why they decided. It certainly was not just a matter of always following an early bent" (p.109). For our students, they have all been following "an early bent," perhaps similar to Roe's physicists: "More of the physicists than of the other groups showed early interests directly related to their later occupations, but this seems quite clearly to be due to the common small-boy preoccupation in this country with physical gadgets--radio, Meccano sets and so on." We were very tempted to ask these students if they were fond of Legos™, but we did not. The major similarity is that all of the students work hard and devotedly. As long as it involves graphic arts, the students are satisfied with their work.

Table 5. Characteristics of Participants Against Roe's Characteristics of Scientists-Altruism

	1	2	3	4	5
Concern for others	T	T	T	T	T

T = true; F = false; NA = not applicable; ND = no data

The altruism expressed by our participants is as intense as that of the Roe's social scientists, who show "intense concern over interpersonal relations generally" (p.106).

Participant attitudes toward science before the ACCD class

Having come to understand something of the background of these students, we then looked at the attitudes they had about science before they participated in the ACCD course. The only editing done was for spelling.

> Student Number One is from Europe.
>
> "As far as I remember, my first contact with the subject of science was in my first year in elementary, it was called 'Sachkunde', in English it means more or less - how things work. The main purpose of the class was to make kids interested in science. In my years at high school, I had to take courses like chemistry, physics, math, but with a special focus on engineering. (It is a high school specialized in educating the students for the engineering branch in industry). Unlike other high schools in Germany we had additional courses in 'Structure

Physics', 'Electricity', 'Electronics', 'Digital Processing', and a few others I can't recall.

(I was an) “average” (student).

“I think at the beginning of my school 'career' I had more enthusiasm regarding scientific topics, during my time on high school I lost this enthusiasm because it was getting too much of a 'work-thing' in other words you had to learn formulas and numbers by heart, which is not my way of working, I preferred to be satisfied with the fact of knowing how something works, or what effect it has on my life (not numbers, or formulas). In my first years in elementary I learned the pure basics of science. In the following years in high school everything was more refined, which was also quite interesting, because I learned always something new, but the final exam was more than a pain, because you where just asked to apply formulas to mathematical problems. (I am not very good at this) This fact also underlines my 'average' in school, because personally I think I have a very good understanding of science in general.

“I am still wondering why I chose to take an educational branch which is so far away from what I started of. Graphic design has not really much to do with science!”

<u>Student Number Two is also from Europe</u>.

“In high school I took two chemistry classes, six math classes, five biology classes and about three physics classes. Three of the biology classes were considered more important, since it was one subject that I had as a graduation class. That means that we had this class about 8 hours a week. (for the last two years of school) When I say three physics classes that means that I took the class for three years.

“I was an average student in all science classes except biology, where I was pretty good. I was very interested and had no problems memorizing scientific terms or understanding certain systems of how things work in a cell for example. For the other science classes I think I just was not interested enough to be a real good student.

“I thought of science as being very complex, and very specialized. In some ways it was a little scary , too. There was definitely a sort of fascination about finding out how things work. I guess biology was my favorite because it is the closest to "real life". My interest in science did not expand to the outside of school though. My thinking about science was limited to what we did in school. I did not spent any of my spare time dealing with science.

“My Dad has a doctor in chemistry. Without him explaining things to me my attitude would have been more negative. Tchernobyl happened when I was still in high school and we lived near the Rhein where once in a while there would be some kind of chemical spill that kills a lot of life in it. So generally my attitude was skeptic. Most of my

> science teachers were pretty boring people. I think that had a great impact on not liking physics and math."

Student Number Three is from the United States.

This student did not respond to the email questionnaire. These answers came from his interview. The questions were the same as those for the questionnaire.

> "I had a life science in junior high school and a biology class in high school, and I had like chemistry and physics, combined, maybe it was a semester each. I've had a bad attitude about it. I've never really liked it. All of them. I never really felt a close connection with any of my teachers. I don't know if it was that or the fact that I wasn't interested in it. It was just confusing, all those formulas and equations, and I just wasn't interested. I didn't like it. I didn't see the connection it had with anything I was interested in.
>
> "I took a lot of art classes in high school and I was interested in them, and I had several humanities classes and those courses which I liked a lot.
>
> "I'd say that I was average (in science.) I know that in my last semester of chemistry I got a "D" and my teacher said I know that you're going to go to college and study chemistry. He knew it just wasn't my thing, but I didn't. I know I could have done it, I just chose not to. . . . I never made that connection in high school, I just didn't care. I mean, I couldn't make that till now and I never thought about things like that in high school."

Student Number Four is also from the United States.

Note, the text has not been truncated; this is verbatim from the participant's email answer.

> "Well, the basics: biology, intro to astronomy, health, summer school at the museum of science and industry. Disinterested. ....good student; always asking why do it that way. .....interested in observing. learning; I did not have a preconceived opinion, which might have had a bias effect on my views. ......it is interesting to watch and wonder why things are the way they are. I've noted that the majority of people are not interested in knowing why this works like this."

Student Number Five is from the United States.

This student did not respond to the email questionnaire. These answers came from his interview. The questions were the same as those for the questionnaire.

> "Junior high had a Earth Science, another sort of science, which was more chemically side, chemistry, things like that. Did that Bunsen burner thing, and things with the rock, porous and the hardness, and, high school had biology class and plants. And I remember seeing a video, the whole sex thing, reproduction, osmosis. Back to junior

high, the first science class was about clouds and precipitation. High school there was life science. I don't remember of the chemical side in high school. I don't remember there being that much. Junior college there was physics, velocity, periodic table and motion, speed, work, force. Light, Lasers."

(Tell me what kind of science student you were. I'm not looking for grades, just a general description. Good / average / poor, interested, disinterested, bored, curious, not curious, and you don't have to relate it to any one of those classes, just sort of in general.)

"To be honest, all of them. It depended on the day and the subject.

"I would say interested in wave form, highs and lows in mid range, nothing extreme.

"It seemed very different from everything else. It seemed like a completely different world. I remember in these physics classes where you'd actually do the experiment, that was the fun part, and maybe you'd record it or write something about it and ... or seeing ... you know, you'd do the experiment and go out and you'd kind of manipulate it to make your own little something. There is instant result. You do it and there's your result. The math is just .... I did like math, figuring out puzzles and stuff. But it just seemed so repetitive, the same thing."

(Was this the attitude that you had that produced this--this kind of wave like pattern?)

"In the beginning, yes, being projected as having something to do with science, and then you get this feeling or this notion of what science is supposed to be and then when we went up north, then I extracted something and my view changed because now I was interested."

The data indicate a fact that has been shown time and again: the two European students took far more science in school than did the Americans. All of the participants believed themselves to be good or average students in science. Three of the participants enjoyed science, because it appealed to a need in them to "find our how things worked." The American students were uniform in their dislike of the mathematics component of science, even the one who indicated that he was good in mathematics. The prevailing attitude of the Americans, supported by one of the Europeans, was that science seemed to have no connection to them in their everyday lives. It was, as student number five put it, "a completely different world." We noticed that despite their lack of interest in "school science," the students had a good grounding in the basics. We also noticed that despite their lack of interest in "school science," the students were not totally disinterested in science in general. They were interested in nature, in how things work, and in hands-on exploration and investigation.

Participant attitudes toward science after the ACCD class

Having learned about their background in science and their attitudes toward science before the class, we were then interested in whether the class had effected any change in these attitudes.

Student Number One

(Was this your attitude when you entered the ACCD class that involved the science at Lawrence Livermore National Laboratory?)

"Yes, but I think I was more open to the subject, as I would have been when just had finished high school, because back then I had enough of science."

(Has your attitude toward science changed since taking the class?)

"No, I don't think so. It was just refreshed. I think I learned to conceptualize better. Teamwork, working together with (student number one). Working in a different way, unlike other projects I did until now."

Student Number Two

(Was this your attitude when you entered the ACCD class that involved the science at Lawrence Livermore National Laboratory?)

"Yes."

(Has your attitude toward science changed since taking the class?)

"I do not think that my overall attitude changed. It might have become clearer. I still think that science is very useful and cannot be stopped even if we wanted to. It has it's very dangerous sides that have to be dealt with in a different way then it has been done in the past. I think the people have to understand science better in order to gain more control.

"I learned the fine distinction between technology and science, which was not as clear to me when I started the class. I looked at a lot of writing on science and ethical\moral issues. Articles on how science effects our thinking and perception of the world."

Student Number Three

This student did not respond to the email questionnaire. These answers came from his interview. The questions were the same as those for the questionnaire.

(So this was the attitude that you had when you first came to this class?)

"Yes."

(Did your attitude change after taking the class?)

"Yes, I think my attitude changed. Yes, I think what I did was I found a portion of science I was interested in. Kind of the more spiritual, mystic, like Jung and Mandalas and Buckminster Fuller who people thought he was a little strange I kind of found that part of science that I like and branched off to that. I'm sure there would be people who would say that this isn't science because it's not as solid as equations and lasers and labs, it's a little bit more what I like. But it made me realize that there is a connection between it, although I don't think I would go take a chemistry class now, although I'd probably appreciate it and I'd find something to apply to art, but it's not I don't think I'm not that interested in it, but I realize that the connection is there."

(Do you think this change is the result of the class?)

"Yeah."

"I think I learned that science is a lot more like art than I thought. When it's taught, it seems like it's taught like this is how it is, only these equations. It seems like a lot of the things the Lab discovered are discovered by chance. I don't have any examples, but how they're studying some thing else, all of a sudden they come up with something else, like that thing that beeps when the car backs up or they randomly discover. It's exactly pretty much the same way I came up with the book. It's not really all formula."

<u>Student Number Four</u>

The text has not been truncated; this is verbatim from the participant's email answer.

(Was this your attitude when you entered the ACCD class that involved the science at Lawrence Livermore National Laboratory?)

".....NO I've concluded that people need to reawaken to the fact that we are part of systems, we are part of families, communities, ecosystems and that's a fundamental identity for us. Americans are obsessed with personality and individualism and if we don't reawaken to this fact we basically don't survive."

(Has your attitude toward science changed since taking the class?)

".....My attitudes toward science have not change much, the only thing that has dawned on me, since learning about LLNL, is we have technology that could forward my ideas into reality.

"......About the way things work in science, not much. But in a certain sense I have learned much about the way things work regarding peoples attitudes towards the betterment of man. I've learned that progress is not as good as it sounds. P.S. those liquid smoke crystal things were pretty neat."

<u>Student Number Five</u>

(Has your attitude toward science changed since taking the class?)

"I wouldn't say taking the class, but, ugh....

"No.

"I guess my cousin is a biochemist and he did an article in a local magazine and he had an example of some diagram and it was just that language, or an example of like how powers go, and with a two, and his

> seemed to be about 10 inches long, so, uh, coming back, it made me see more deeper into what science is. Like there's a lot more depth, and just being more aware."

Following the class, three students -- the two Europeans and one American -- who had had positive ideas about science when they entered the class, found those ideas "refreshed," "become clearer," and reinforced. The other two American students changed their attitudes: "I found a portion of science I was interested in;" and "it made me see more deeper into what science is." Two students discovered a deeper meaning in the difference between science and technology, and one student was able to see a strong connection between art and science. We noticed several themes in the interviews:

- an interest in, and a fascination with technology,
- a sense of spirituality, as opposed to religiosity,
- a strong sense of ethics,
- a reflection of the altruism indicated in their background characteristics,
- an idiosyncratic view of science,
- indications that they viewed science in a way similar to the way they viewed art.

<u>Participant final products</u>

When we began the analysis of the students' final projects, we reviewed the themes that we had developed from the general literature and the from the manifesto created by the two professors at ACCD. We decided to concentrate on the following themes:

- to look beyond the surface and make a complex idea clear,
- to look for an underlying order to the seeming disorder in our world,
- to view and understand science as an open-ended exploration,
- to view science as a collective -- a social --practice with individuals across cultures and time sharing observations,
- to view science as an effort in which anyone can engage,
- to view the "big ideas,"
- to concentrate on major themes, and examine them in depth.

We were also interested to see if any of the themes we had noticed in the interviews would be reflected in the art projects.

<u>Students One and Two</u>

The two European students worked on the final project together. Student One was responsible for the original graphics. Student Two selected the text, and both were involved in the selection of the photographic art. The product as a whole demonstrates both students' interest in using their chosen field as a medium to express their understanding of, and interest in, science. The technological background of Student One, and the newly acquired understanding of technology of Student Two are clear. Another important aspect of the work is the underlying concern for others expressed by both, as well as their reflections on the ethical needs of man in relationship to science. Thus, there are several of the interview themes that carry through into the project, e.g., technology, ethics, altruism, science and art are similar. The texts for the product come from such varied sources as Lewis Wolpert, Wired Magazine, Oppenheimer, Hegel, and Asimov. Accompanying the book, from which illustrations are shown below, was an interactive CD-ROM disk that delved into the nature of technology. We believe this work represents a deep understanding of these themes:

- to look beyond the surface and make a complex idea clear,
- to look for an underlying order to the seeming disorder in our world,
- to view and understand science as an open-ended exploration,
- to view science as a collective -- a social --practice with individuals across cultures and time sharing observations,
- to view science as an effort in which anyone can engage.

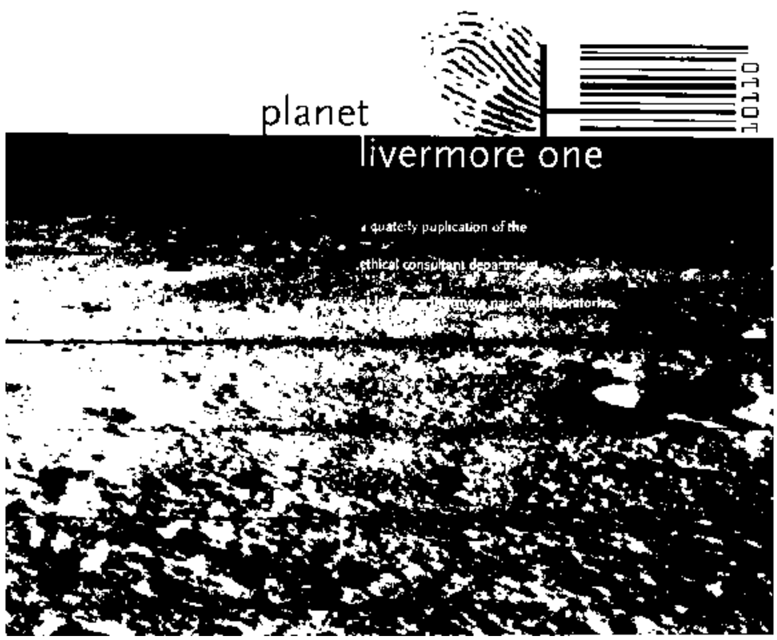

Figure 6. Cover of the book.

The Cover (Figure 6) is entitled “planet livermore one.” It is intended to be the first issue of a publication from the “Ethical Consultant Department” at the LLNL. The students see a need for strong ethics in the practice of science. They believe that a Laboratory such as LLNL should, and could, take the lead in establishing such and office, and also its mission. This idea corresponds well with the altruism in their background characteristics.

Figure 7. Contents page of the book.

The Contents page (Figure 7) shows some of the numerous small technology-inspired drawings of Student One. The contents point to a description of the new "Ethical Consultant Department," an article on the "unnatural nature of science," one on viruses, and others. Notice the use of "worlds" in the graphic. This shows a universality of science.

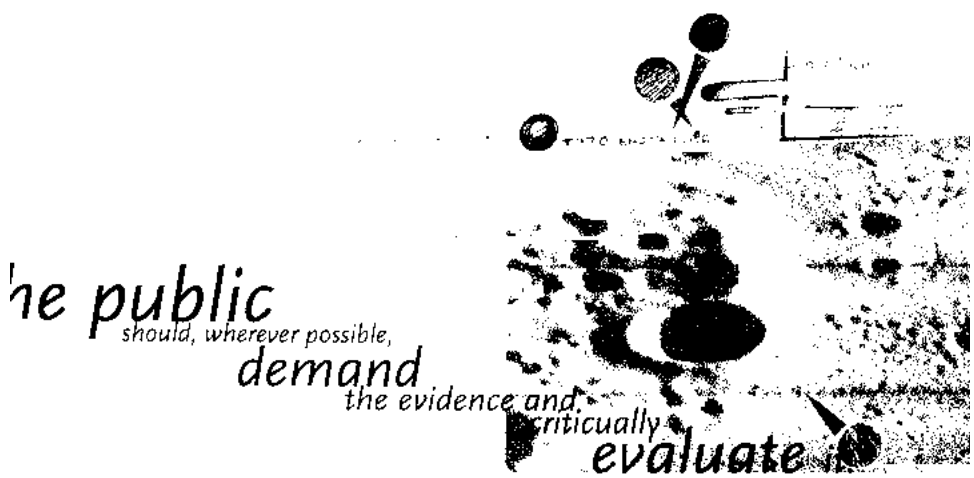

Figure 8. Quotation from Oppenheimer.

Figure 8 presents a quotation from Robert Oppenheimer: "And the public should, whenever possible, demand the evidence and critically evaluate it." The quote is taken from a longer piece by Oppenheimer that accompanies this graphic. The graphic of the surface of the moon carries forward a vision of the future and the universality expressed in the cover.

Figure 9. A signpost for humanity.

We called the graphic in Figure 9 “A signpost for humanity,” because it shows the concern that the students have for others superimposed over a picture of chromosome banding, a major idea in the biological sciences. Accompanying this graphic is a short text from Asimov which summarizes the thoughts and the philosophy that the students put into this product:

> “A public that does not understand how science works can, all too easily fall prey to those ignoramuses... who make fun of what they do not understand, or to the sloganeers, who proclaim scientists to be the mercenary warriors of today, and the tools of the military. The difference... between... understanding and not understanding... is also the difference between respect and admiration on the one side, and hate and fear on the other.”

The sign post itself is the shape of a “YIELD” sign. Yield to humanity. The students have attempted to combine science with philosophy and ethics. They are interested in “raising moral and ethical questions,” not in giving pre-planned answers. This new Department is conceived as a forum for thinking and discussion. The Department publication, “planet livermore one” welcomes diversity by inviting guest contributors; scientists, writers, and philosophers. The students see the publication being sent to schools, universities, and distributed on the Internet

The selection of readings in the product clearly demonstrates the wide-range of reading (one of their strong background characteristics) done by the students: everything from Hegel to <u>Wired</u> magazine.

Student Number Three

This student developed a mammoth book of over 100 pages (Figure 10). The major theme of the book is mandalas, reflecting the spirituality expressed by the student in his interview. In using the mandala as a theme for the future of the Laboratory, he also shows his connection of science and art, in a very idiosyncratic way. This connection is shown in Figure 13.

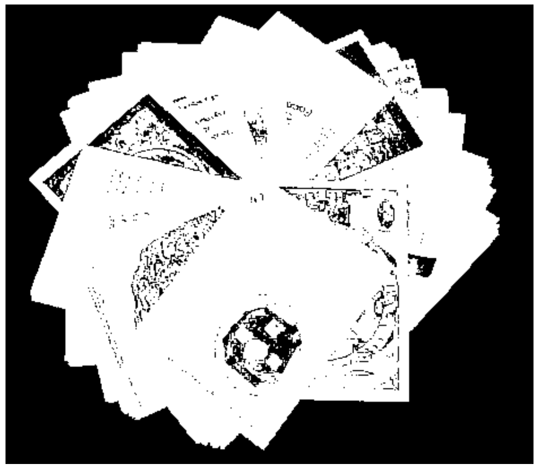

Figure 10. The book opened to show its depth.

The 100 pages are held together by a bolt, allowing the pages to "fan" out in a circular shape of the reader's choosing, i.e., the reader can show as many or as few pages as he or she wishes. The shape IS a mandala. The book itself is comprised of many pages of carefully chosen philosophical texts based on, or about, mandalas. The following text (Figure 11) again shows his connection between the mandala and the Laboratory.

The mandala will be the organic counterpart of the lab, to balance out the scientific part.

The mandala has to do with harmony. it is the evolution of the lab.

Nothing exists unaffected by the rest of the world the lab works with the University of California, the government, and the modern consumer.

Figure 11. An example of a text page, showing use of font and size.

This student was interested in using the mandala as a metaphor for the Laboratory. He saw the Lab in need of harmony because it acts upon, and is, in turn, acted upon by other entities. He also saw the Lab as “a reflection of America.” The student felt the mandala could offer LLNL a symbol of reunification.

Another quotation clarifies the metaphor, “In the present struggle of the planet, the mandala represents itself as the seed-symbol of a more harmonized world order.” The Laboratory could be the seed-symbol of an unfolding harmony between science, education, the government, and the consumer.*

Mandalas have been used (“scientifically”) to predict and celebrate the movement of the moon and planets. Stonehenge, seen from above, is a mandala.

One of the things we noticed about these students was their descriptions of fonts; they used words such as “funky,” “professional,” “classical,” and “sedate.” This page makes unique use of font and size to convey feeling.

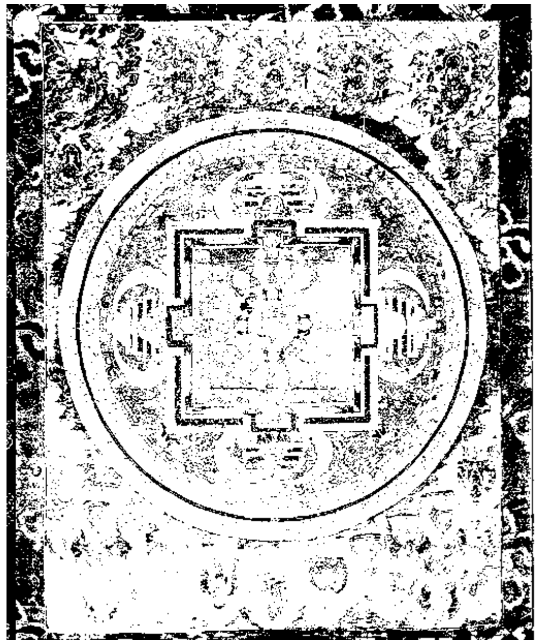

Figure 12. One example of a Buddhist mandala from the book.

Figure 12 is but one example of a mandala included in the book. The student used many examples, religious, non-sectarian, and those he created himself.

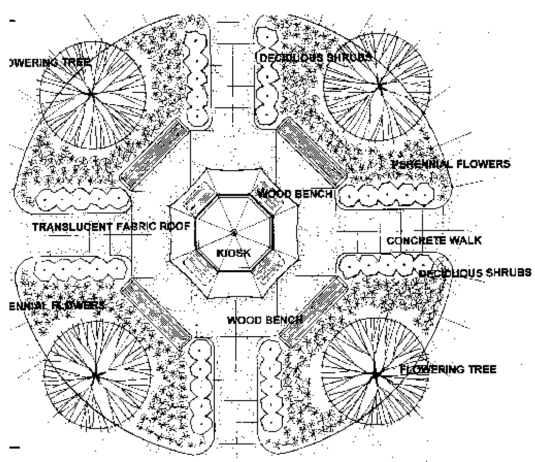

Figure 13. Landscape/architectural drawing of a Laboratory kiosk garden.

This student utilized the concept of the mandala to design for LLNL information kiosks, to be placed in spots around the laboratory grounds (Figure 13). The kiosks were intended to display permanent and temporary information about the different departments that make up the Lab.

They were designed to be very colorful and stimulating, to encourage interaction and unity between departments and employees. The kiosks were intended to be completed with landscaping and benches to enable the employees and visitors to meet, discuss and enjoy the outdoors.

We believe that Student Number Three incorporated the following themes into his work:

- to look for an underlying order to the seeming disorder in our world,
- to view science as a collective -- a social --practice with individuals across cultures and time sharing observations,
- to view science as an effort in which anyone can engage,
- to view the "big ideas."

We believe that he also shows in his work the following themes from the interviews:

- a sense of spirituality, as opposed to religiosity,
- a strong sense of ethics,
- a reflection of the altruism indicated in their background characteristics,
- an idiosyncratic view of science,
- indications that they viewed science in a way similar to the way they viewed art.

Student Number Four

Like Student Three, this man carried many of the same interview themes through in his work:

- a sense of spirituality, as opposed to religiosity,
- a strong sense of ethics,
- a reflection of the altruism indicated in their background characteristics,
- an idiosyncratic view of science,
- indications that they viewed science in a way similar to the way they viewed art.

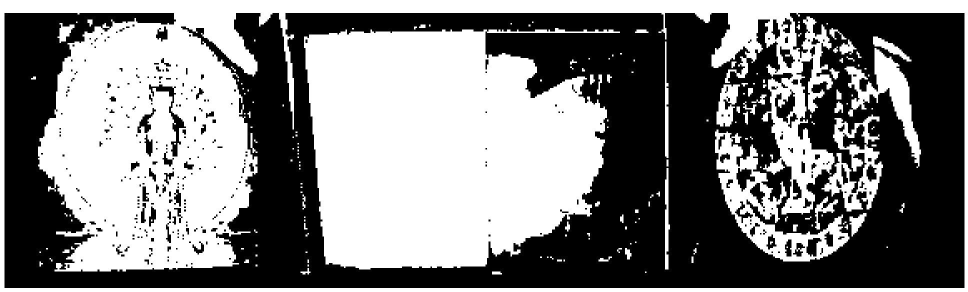

Figure 14. The book opened to show the four quadrants of pictures.

Figure 14 shows only a part of this student's book. The book opens both to the left and the right. Depending on how many pages are opened on either side, the reader obtains a juxtaposition of natural and man-made artifacts. These artifacts are always of a scientific nature, whether man-made items of technology, or phenomena such as a meteor crater. Textual pages, are intended to be read together in the center quadrants, with illustrations on the left and right.

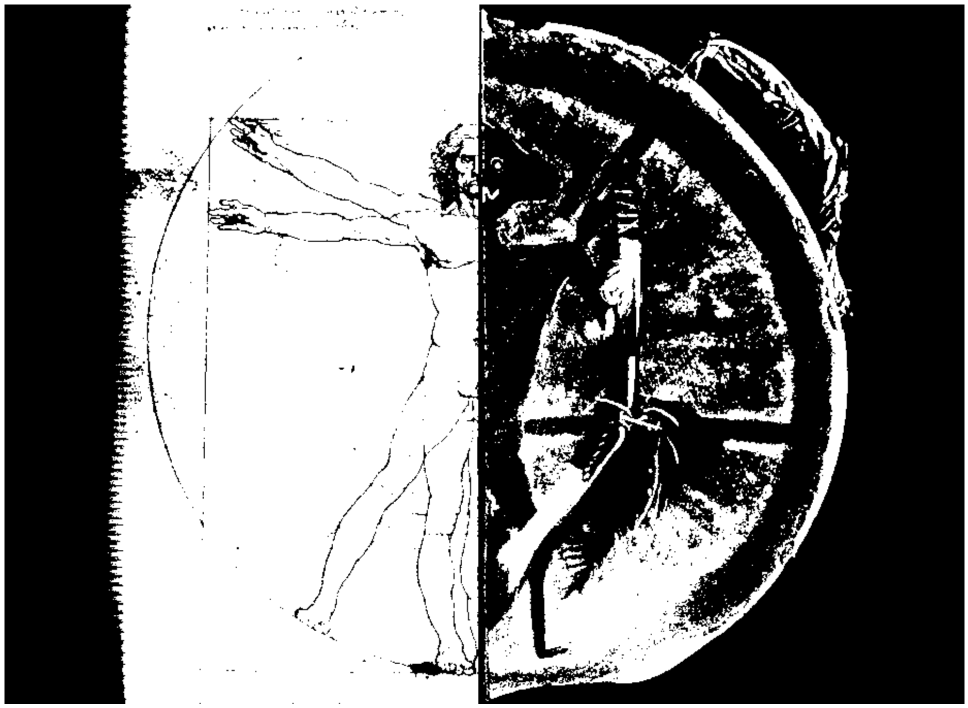

Figure 15. The cover of the book.

The left half of the cover (Figure 15) is the da Vinci drawing of the ideal proportions of man. Man as the measure of all things. The right half of the cover is by contrast, more primitive -- a decorated shield. Here man is seen more symbolically, and also perhaps metaphorically. Another contrast is that of the scientist da Vinci opposed and blended with a primitive concept of man, the circle of the da Vinci connecting to the edge of the shield, the two figures, right and left sides of a person.

These kinds of comparisons make up the entire book. There are comparisons between many man-made objects, natural phenomena, and many biological references. These are tied together with sparse text, allowing the graphics to do the “speaking” for the student and his philosophy.

Several of the graphics were of cathedral windows, mandalas, and other religious objects. Tied with the scientifically based graphics, the student particularly brings out the themes of spirituality and that science can be viewed as art.

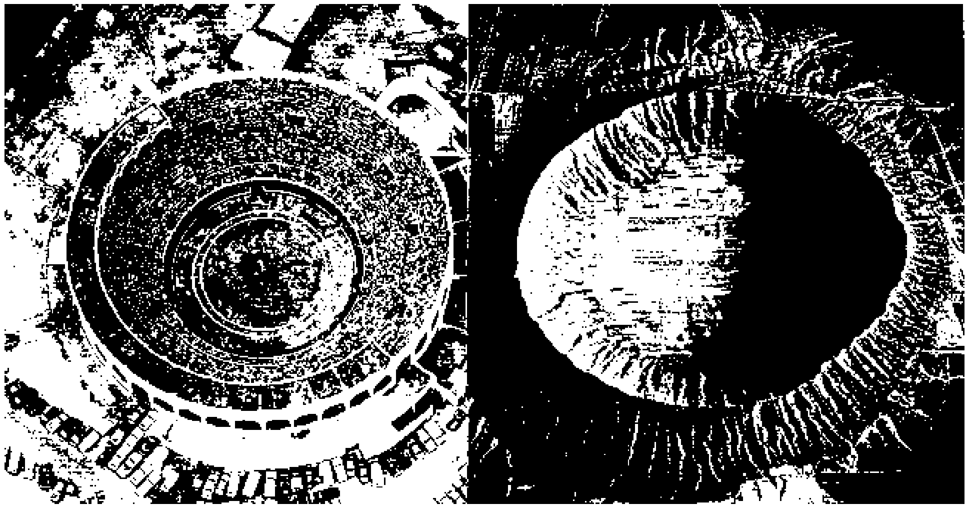

Figure 16. Plaza de Toros and a meteor crater.

The images of the bull-fight and the crater (Figure 16) are circular in shape. The circle connotes unity. This students' entire book is full of circles, from the stone wheel to the universe whirling through space. These circles are intended to be viewed two, three, or four at a time with very little text. The juxtaposition here is that of a man-made engineering artifact against a nature-made artifact. They are so similar in size relative to the creator of the artifact.

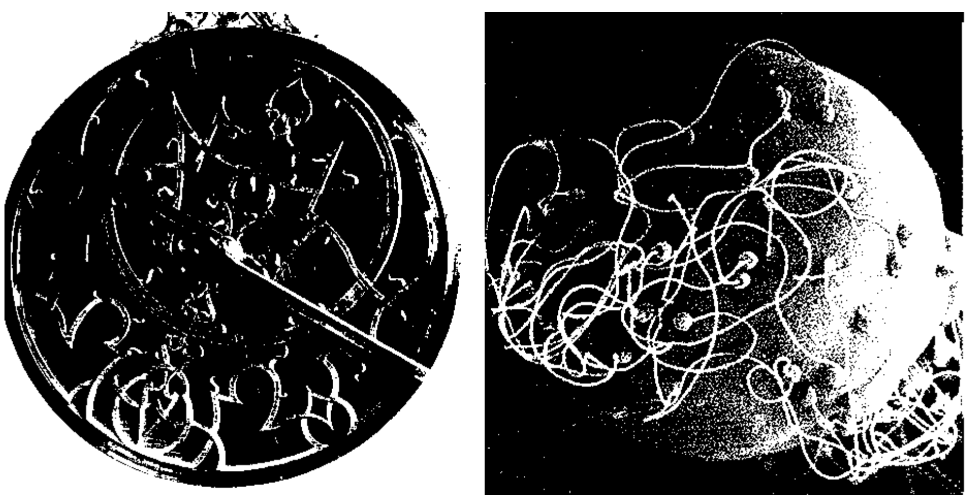

Figure 17. Astrolabe and human ovum.

This juxtaposition of the 15th century astrolabe with the human ovum besieged by sperm (Figure 17) is one of this student's astounding correlations of circles; the mechanistic with the organismic. Note the contrast between the filigree decoration on the man-made technology and the tails of the sperm as they circle and entwine the egg.

We believe that this student demonstrated the following themes in his work:

- to look for an underlying order to the seeming disorder in our world,
- to view and understand science as an open-ended exploration,
- to view science as a collective -- a social --practice with individuals across cultures and time sharing observations,
- to view science as an effort in which anyone can engage,
- to view the "big ideas."

Student Number Five

This man took one small part of the Laboratory's work and developed it with great insight and sensitivity. After the tour of the Lab, the students met with one of our scientists, who discussed areas of the campus that the students had not visited, one being the Biomedical Program. He talked at length about LLNL being part of the nation-wide Human Genome Project. During this talk, the scientist mentioned that one of the discoveries the Lab had made was the gene for dwarfism. Here is the product the student developed from that one sentence spoken at the end of a long tiring day. We believe this work represents a deep understanding of these themes:

- to look beyond the surface and make a complex idea clear,
- to look for an underlying order to the seeming disorder in our world,
- to view science as a collective -- a social --practice with individuals across cultures and time sharing observations,
- to view science as an effort in which anyone can engage,
- to concentrate on major themes, and examine them in depth.

The student who produced this work had deep concerns about the development of this book. He did not want to transgress from the medical aspects into a book that verged on voyeurism, so he stuck with the medical aspects very closely. He was also concerned that he would say something in the book that would be viewed as insulting to the people who have achondroplasia. He also wanted to develop a book that would educate people. In so doing, he educated himself.

What he completed was a work of great depth and sensitivity. It is not technical, but it shows an understanding of achondroplasia that is beyond what the general public would have. It is an educational work. It is also done with great beauty and insight.

The cover of the book is shown in Figure 18.

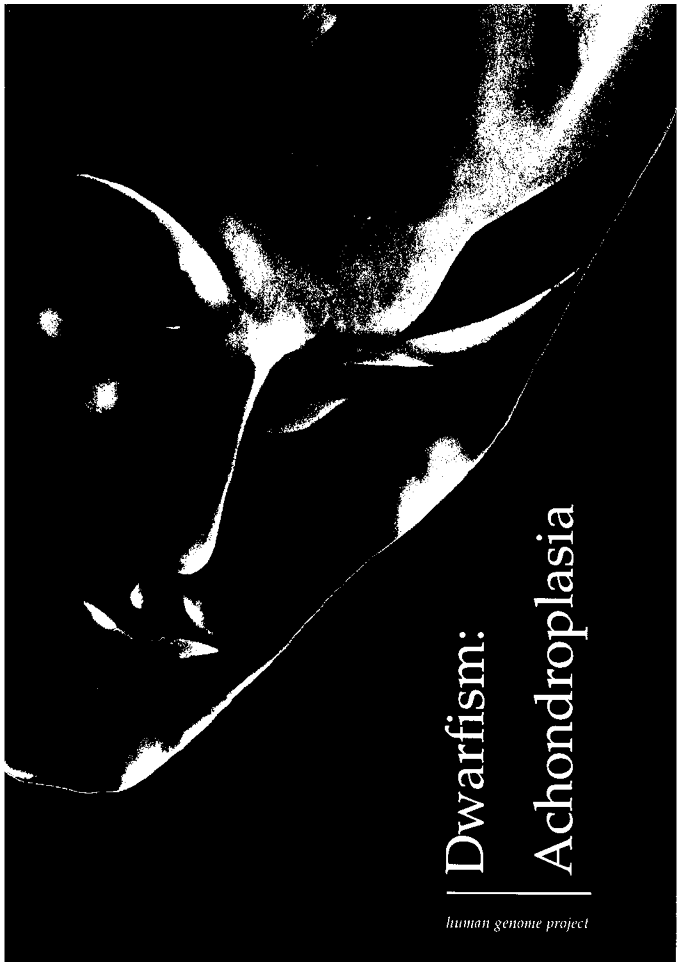

Figure 18. Cover of the book.

This student said that he had not created this image (Figure 18) specifically for his book on achondroplasia. He utilized a pre-existing painting that he had done to explore another subject. This mask like face has a fetus in the place the brain would be. The painting was used because it spoke eloquently to the inheritance factor of dwarfism.

The colors and the aspect of the face seem to indicate, immediately, that this is not a traditional approach to the subject. It leads the reader directly into a serious frame of mind. This seriousness is also reflected in the choice of font.

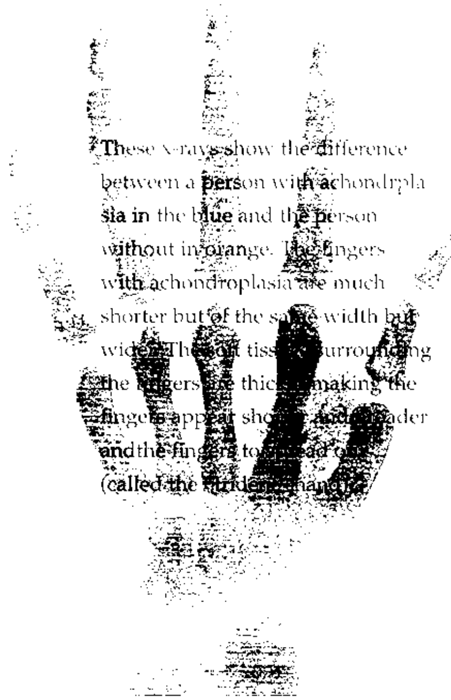

Figure 19. X-Ray comparison of hands.

This image is an X-ray composite of a normal hand in orange, and a person with achondroplasia in blue. The fingers with achondroplasia are shorter and the first two digits curve toward the thumb. Even when relaxed, these fingers spread out. This is referred to as the “trident” hand. We thought this a unique, and thoroughly artistic way to represent the differences caused by the genetic fault; the usual method is to show photographs of the individual.

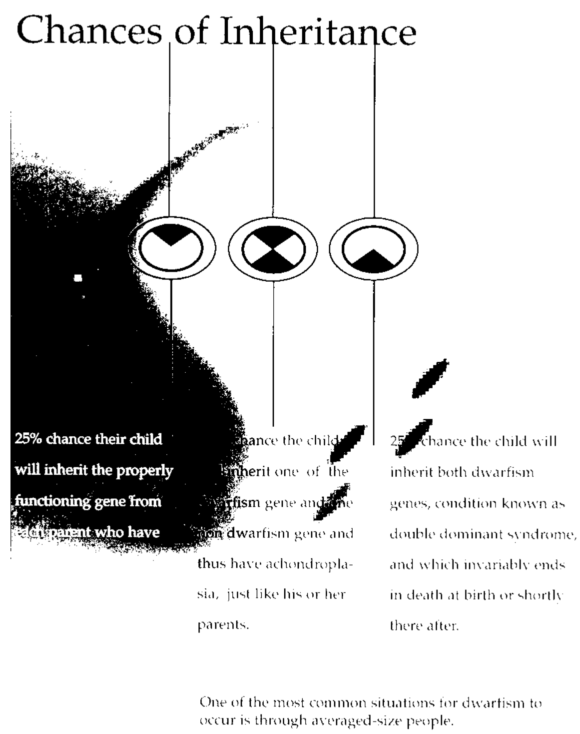

Figure 20. Inheritance of achondroplasia.

We found this graphic to be interesting in its use of a stylized human ovum, divided to show the genetic chances of inheritance.

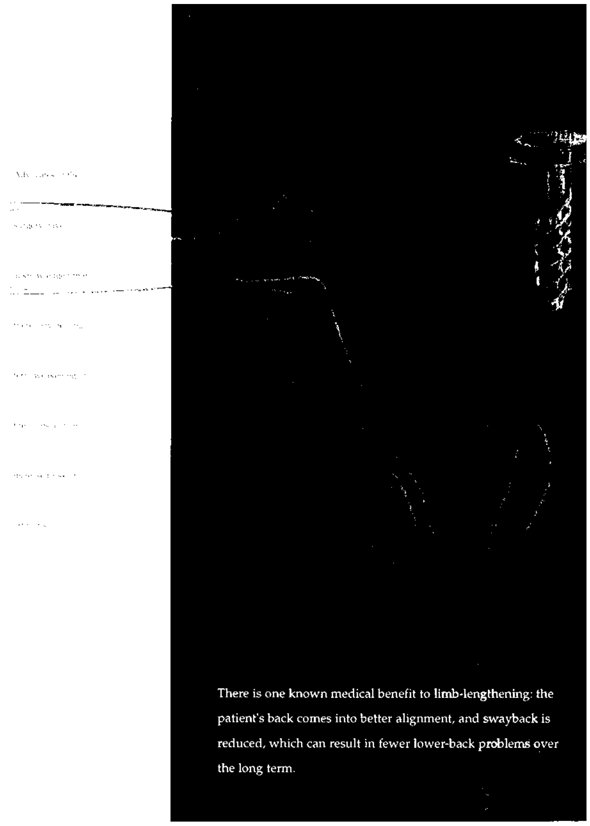

Figure 21. Limb lengthening.

This drawing accompanies a page entitled “Limb Lengthening” and explains the process which involves cutting arm and leg bones, inserting pins and moving the bones apart. New bone tissue then fills in the gap, increasing length. The very mechanical screw placed inside the arm of the person with Achondroplasia effectively illustrates the process.

Even the few graphics we have shown from this work demonstrate that the student has expressed many of the themes from the interviews, particularly:

- a strong sense of ethics,
- a reflection of the altruism indicated in their background characteristics,
- an idiosyncratic view of science,
- indications that they viewed science in a way similar to the way they viewed art.

Discussion

The participants in our study had many of the family, intellectual, social, and career characteristics of scientists. All had either a very basic or a limited scientific background. For the most part they seemed to have an innate interest in things scientific at an early age, but had become disinterested in “school” science, and had self-selected out of this profession at about the high school years. The ACCD class, while not providing a strong academic background in science, nevertheless had kindled, or refreshed, an interest in science that was unique and personal to each student. These interests and understanding are clear, both in content and personal expression. Despite the lack of science as a core interest, the students were able to depict, in an artistic form, the “big” science being conducted at the Lawrence Livermore National Laboratory. In addition, they were able to show, graphically, many of the major themes discussed in the literature, particularly the following:

1) to look beyond the surface and make a complex idea clear. This theme is especially clear in the student-artist’s work on the achondroplasia book.

2) to look for an underlying order to the seeming disorder in our world. Student’s One, Two, Three, and Four followed this theme throughout their work, particularly drawing together ethical and spiritual ideas with science.

3) to view science as a collective -- a social --practice with individuals across cultures and time sharing observations. This theme comes through strongly in the work by Student Four, showing human science from a variety of cultures and time periods.

4) to view science as an effort in which anyone can engage. This theme is shown in all of the work. While it is certainly not in the tradition that any of the LLNL scientists would recognize, these students were actually engaged in science, often with the child-like approach mentioned in the literature.

5) to view the “big ideas.” Students Three and Four looked at this theme from both a cosmic-spiritual level, and from a variety of cultural levels as well. Students One and Two looked at the major ethical issues involved in science.

6) to concentrate on major themes, and examine them in depth. This was the approach taken by Student Five in his depiction of dwarfism.

The most interesting idea to us was that none of these students worked consciously to bring these themes into their artistic products. The results of these students’ work is almost a meme.[1]

We also learned that these students were able to fulfill some of the criteria proposed by their faculty, namely:

1) critical thinking and exploration, demonstrated in the achondroplasia work and the ethical concerns of Students One and Two.

2) look beyond the surface and make a complex idea clear, demonstrated in the achondroplasia work.

3) create individual statements, strongly demonstrated in all of the

[1] meme: (pron. 'meem') A contagious idea that replicates like a virus, passed on from mind to mind. Memes function the same way genes and viruses do, propagating through communication networks and face-to-face contact between people. Derived from the word "memetics," a field of study which postulates that the meme is the basic unit of cultural evolution. Examples of memes include melodies, icons, fashion statements and phrases.

work that we viewed.

4) an understanding science and history, as shown in the work of Student Four.

Again, none of this learning was a conscious effort, but it was able to show the instructors that their approach was worth continuing.

As a result of this study, we have become particularly interested in the different processes that can be used to teach science to non-scientists, so that they are able to understand and portray scientific information. For non-science majors, it is clear that there are other modes of investigation and inquiry, and there are other modes of representation of knowledge than are used in traditional science inquiry.

This study has several limitations, which, if we are able to continue the work, or if others can replicate the study, can be mitigated.

First, we believe that Roe's study needs to be brought up to date. What obtained in 1952, may be quite different today.

Second, we would have liked to have had more participants in our study. This study would have been particularly enhanced by the addition of one or more female students. It would also have been enhanced by having students with greater ethnic diversity.

Third, due to our distance from the participants, it was not possible to observe them at work or use a long interview process as would be found in an ethnographic study.

Conclusion

Both science and arts education allow learners to learn by doing and creating. The prime motivations in a science or art program are to:

- offer learners opportunities to enhance learning,
- provide opportunities to learn various concepts by non-traditional means,
- provide opportunity to express mastery of content through presentation,
- develop self-discipline and self-control.

The overall purpose of providing educational programs in the visual arts is to produce aesthetically responsive citizens with life-long interest and involvement in the arts. The specific goals for the learner in any arts education program are to:

- Expand avenues for communication and self-expression,
- Develop a capacity to enjoy aesthetic expression and sensitivity and responsiveness to the expression of others,
- Develop Skills and craftsmanship for effective expression in the arts,
- Develop The ability to use the arts to synthesize one's feelings about objective facts,
- Develop Aesthetic sensitivity,
- Develop Intellectual bases for making and justifying aesthetic judgments based on an understanding of the nature, structure, and

meaning of the arts,

• Develop Appreciation of the role of creativity in human achievement,

• Develop the capacity to experience aesthetic qualities in the environment,

We believe that the addition of an artistic side to science would afford scientists with these same qualities. The arts can, and should, play a major role in science. Each art is unique, because of the particular avenues of perception that it develops. Increased perception sensitizes the individual to the world. As one develops a fuller awareness of the nuances of light, color, sound, movement, and composition through experiences in the arts, otherwise ordinary experiences take on an aesthetic dimension. Heightened perception provides a stimulus for imagination and creativity and has impact on all learning. In the arts, the development of aesthetic perception enables one to comprehend and respond to the elements of an object or event and to express and appreciate it in greater depth.

Creative expression includes originating, creating and presenting, and interpreting; focusing, channeling, and encouraging communication and originality, and providing increasing understanding of the structure and language of the arts. Creative expression helps one to know one’s self and to appreciate one’s own and others’ uniqueness. It generates excitement, encourages creative exploration, and enhances learning. This expression can be useful in science as well.

Life is enriched as the awareness and response to beauty in all of its forms increase. To develop aesthetic values, the student studies the sensory, intellectual, emotional, and philosophic bases for understanding the arts and for making judgments about their form, content, technique and purpose. Through study and direct experience, the student develops criteria for arriving at personal judgments. As Students One and Two have pointed out in their work, these elements should, and could be important in science.

We believe that any advance in knowledge concerning the creative process is of value in education, particularly if the study is able to follow the process from the germ of an idea through its development and embellishment to the final, physical, artistic product. Further, we believe that this study can contribute to the literature on science education, art education, cognitive change, and public understanding of science. We hope that our codes and themes will prove useful to future investigators in the development of correlational studies and experimental treatments related to this topic.

Future researchers can correlate these modes of thought and interactions to other criteria. For example, one of the most important themes that emerged from this data is the need for science and mathematics to be taught in a more visual way to these visual learners. Effective strategies that emerge from the correlational research can inform instructional programs that can be tested in experimental research.

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Appendix A - Interview and Survey Questions

Set 1 - Related to Science background
1) Please describe any science classes you have taken since elementary school. Be as detailed as possible.

2) Please describe what kind of science student you were. We are not looking for grades, just a general description, e.g., good, average, poor, interested, disinterested.

3) Please describe your attitude toward science during this period of time (since elementary school).

4) Please describe any reasons you can think of that may have had an effect on the answers to questions 2 and 3.

5) Based on your answer to question 3 above, was this your attitude when you entered the ACCD class that involved the science at Lawrence Livermore National Laboratory.

6) Has your attitude toward science changed since taking the class? If so, please describe in what ways it has changed? Could it be said that this change in attitude was a result of the class?

7) In a general way, please describe what you learned about science as a result of the class. Please note that this question is about content, not attitude.

Set 2 - Related to art and creativity
1) Did your concept/project evolve in your mind as you drew?

2)When do your creative ideas come to you? (Example: in the shower, while driving, etc.)

3) Where did the germ -- the first bit of the idea for the project come from:

- Words spoken on the tour of the lab?
- A picture seen on the tour of the lab?
- Word in the written literature?
- A scene in the video shown on the tour of the lab?
- No specific picture or word sequence?

4) How did you research your original idea?

5)What shape did the development of the idea take?

6) Did you interview anyone for this project?

7) How many hours do you estimate this project took?

8) Are you emotionally involved with your project in any way?

9) How do your thoughts come to you? (Example: in words, pictures, shapes, etc.

Set 3 - Related to background characteristics
1) Are you right or left handed?

2) Are you a first, second, etc., born child?

3)What is your approximate IQ? (Remember these answers are confidential)

4) Do you consider yourself an introvert or an extrovert?

5) Were you healthy or sickly as a child?

6) Are you primarily a visual or verbal learner? visual or verbal thinker?

7) How do you view religion?

8) What kinds of extracurricular activities did you participate in when you were in high school? What do you do for recreation now?

9) In high school, were you shy and/or aloof from classmates?

10) When you were younger, were you independent of your family?

11) Do you have a strong concern for other people?

12) Have you decided on a SPECIFIC career? If so, when did you make this decision?

Set 4 - Related to background characteristics
1) As a child, were you an avid reader? What about now?

2) Do you like movies?

3) Do you like social affairs (parties)?

4) Are you involved in political activity?

5) Is your interest in women, less than moderate, moderate, more than moderate?

6) Do you do better on non-verbal or verbal tests?

7) Have you ever taken a test of your spatial abilities? Did you score high medium or low?

8) Do you score high medium or low on mathematical tests?

9) Were you rebellious as a child?

10) Was learning a high value in your family?